University of South Carolina

Seismic Reflection Technology for the Detection of DNAPLs

Technology Need:

Locating subsurface Dense Non-Aqueous Phase Liquid (DNAPL) contamination is difficult using conventional characterization methods, such as drilling and groundwater monitoring. DNAPL may exist as relatively small pocket of free product, the location of which is difficult to pinpoint. Non-invasive characterization methods, capable of scanning and imaging large subsurface areas are needed to locate these hard-to-find DNAPLs.

DNAPLs behave uniquely in the groundwater; they dissolve slowly and tend to migrate by gravity rather than in the direction of groundwater flow. DNAPLs often migrate downward until a low permeability layer is encountered. DNAPLs may migrate laterally and eventually accumulate in a dip or low point in a formation. Pinpointing the locations of DNAPL source areas is a critical step in remediating the groundwater contamination. Existing characterization technologies and approaches are costly and have not met the needs of environmental managers for locating DNAPLs.

Technology Description:

Seismic reflection technology is a non-invasive, geophysical technique that is capable gathering information about the subsurface used to generate images of geologic strata and DNAPL contamination. Other valuable subsurface characteristics such as porosity, permeability, and clay content can also be determined. The use of seismic reflection to map geologic stratigraphy is not new. The innovative aspect of this project is a data analysis method, called Amplitude Versus Offset (AVO), which can be used to detect the presence of DNAPL contamination. Direct detection of DNAPL using AVO, in conjunction with images of stratigraphy, provides environmental managers with new insight regarding pathways for DNAPL migration and location of DNAPL contamination.

To show one example of the output from a seismic reflection survey, a contour map of seismic amplitude values for the top of the caliche layer at the Hanford site is presented in Figure 1. The amplitude values were found to correspond strongly to presence of carbon tetrachloride.

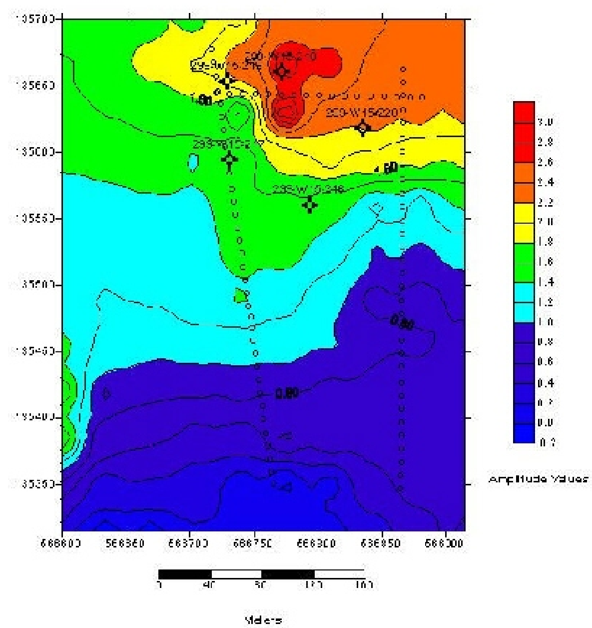

Figure 1. Seismic Amplitude Values for the Top of the Caliche Layer at Hanford.

Seismic reflection surveying has been used since the mid- 1920's to map subsurface geology - primarily for petroleum exploration. However, the use of the method for environmental applications did not begin in earnest until the early 1980's. Although, the principles are similar for both applications, the environmental application is done on much smaller scale and requires higher resolution of features.

In the seismic reflection method, the arrival time and amplitude of elastic waves, generated by an artificial source and reflected from subsurface layers, are recorded and analyzed. The ability of seismic data to resolve geologic features is governed by the spacing of the sensors (geophones) on the surface, the frequency of the reflected signal, and the velocity structure of the subsurface. The reflected seismic waves are picked up by transducers known as geophones. The recorded signal is processed to create a seismic profile of the subsurface layers. For a typical seismic survey several hundred geophone locations are required to ensure adequate subsurface coverage. Seismic reflection data acquisition can be done as either two-dimensional or three dimensional recording.

AVO analysis for the detection of DNAPL involves comparing modeled responses with field data to find a deviation from an expected background response. The use of AVO is based on the premise that presence of a pure hydrocarbon (i.e DNAPL) in a reservoir (or aquifer) can cause a large enough change in the Poisson's ratio of a material that a significant change in seismic reflectivity occurs as a function of the angle of incidence of impinging energy (or source to receiver offset).

Benefits:

▸Capable of investigating large subsurface areas, whereas conventional methods rely on few monitoring points to characterize relatively large areas.

▸Generates detailed images of subsurface lithology including potential migration pathways and low points where DNAPLs tend to accumulate.

▸Non invasive nature minimizes potential for mobilizing contamination.

Status and Accomplishments:

The University of South Carolina's Earth Science and Resources Institute, has demonstrated the technology at Savannah River Site's M-Basin, Hanford's 200 West Area, the Pantex site, and the Charleston Naval Weapons Station. The technology is also scheduled to return to SRS to perform a seismic survey at the location of the Dynamic Underground Stripping (DUS) project.

The SRS Demonstration utilized seismic reflection technology to image a known Tetrachloroethylene (PCE) DNAPL plume. The seismic survey targeted the upper interface of the "green clay" aquitard that is present at a depth of approximately 47 meters below ground surface. The images generated from the seismic surveys successfully located DNAPL at a number of locations, several of which were verified by existing wells or confirmed by new drilling and sampling.

At the Hanford site, a seismic survey was conducted and images were generated of the interfaces between prominent geologic layers where free phase carbon tetrachloride (CCl_4) was suspected to be present. The AVO method was successfully utilized to generate images showing areas saturated with CCl_4.

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Online Resources

Office of Science and Technology, Technology Management System (TMS), Tech ID # 2306
http://ost.em.doe.gov/tms

The National Energy Technology Laboratory Internet address is http://www.netl.doe.gov